A demonstration trial to test the fuel efficiency properties of the Fitch unit for waste collection vehicles and to assess the environmental and financial impacts of the fuel efficiency outcomes.
Our vision is a world without waste, where resources are used sustainably.

We work with businesses and individuals to help them reap the benefits of reducing waste, develop sustainable products and use resources in an efficient way.

Find out more at www.wrap.org.uk
Executive summary

Whilst the waste sector has developed new technologies and infrastructure over the past 10 years for recycling and recovery of waste, the logistics of commercial waste collections has remained largely unchanged. In order to promote and facilitate good practice, WRAP (Waste & Resource Action Programme) has funded a series of demonstration trials to support the development of the waste (and construction) industry towards a more efficient logistics model for waste collection.

This demonstration trial (one of a series of three delivered under the MRF114 project), investigates the potential benefits of the use of the Fitch unit, which can be retrofitted to most engine types and uses a poly-metallic amalgam catalyst to improve the quality of the fuel, requiring less fuel to be used and reduces emissions.

The trial used Btrack units (modular units attached to the engine to measure fuel flow and GPS location) to accurately measure fuel consumption on three refuse collection vehicles (RCVs) operated by Premier Waste in the Birmingham area. Two vehicles were retrofitted with the Fitch units (supplied by Fuel Harmonics) during the six-month trial, comprising one single modal (skip) vehicle and one multi modal (compaction) vehicle. A control vehicle was also operated without the Fitch unit installed, this being a single modal (skip) vehicle. The test subject vehicles had defined and consistent areas of operation and the overall load and manner of collections remained constant throughout the trial period.

The results show that the single modal control vehicle (without the Fitch unit) delivered relatively constant fuel efficiency in the range 9-10 mpg over the trial period. The weighted averages of the two vehicles fitted with the Fitch units showed results demonstrating little change following fitting of the Fitch units. The results are summarised as follows:

- The single modal vehicle achieved 9.5 - 10.5 mpg prior to Fitch unit fitment and 10mpg following fitment.
- The multi modal vehicle achieved 3.5 - 4.5 mpg prior to Fitch unit fitment and 4mpg following fitment.

The main finding from the analysis is therefore that there was no significant difference to the fuel efficiency of either test vehicle prior to and following fitment of the Fitch unit. The study highlights that variations both within each vehicle’s dataset and between the relative measured fuel efficiencies of the three vehicles may be explained by factors such as very short trips, the stop-start nature of the collection round and driving style.

The trial highlighted the differences between the use of single and multi modal vehicles, with analysis of the data showing a significant difference between the average fuel efficiency achieved by single modal vehicles (9 - 10mpg) and that of multi modal vehicles (3.5 - 4.5mpg). Through the trial analysis and the wider data gathered on the MRF114 study, single modal vehicles were also found to travel much further each week (560 - 685 miles per week) when compared to the multi-modal vehicle (250 - 375 miles per week). Despite this difference the actual distance travelled per tonne of waste collected via the two service modes was comparable.

Our analysis has generated some initial benchmark figures describing key logistics parameters for the two service modes. From this, single modal vehicles typically collected 18 tonnes of waste per day compared to 7.28 tonnes per day on multi modal vehicles, which is equivalent to a 147% greater waste mass using 4% less fuel and emitting 4% less CO₂. These differences are further highlighted in the specific consumption figures below:

<table>
<thead>
<tr>
<th></th>
<th>Single modal (14 yd skip) vehicle</th>
<th>Multi modal (compaction) vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance travelled</td>
<td>7.22</td>
<td>7.47</td>
</tr>
<tr>
<td></td>
<td>miles per tonne of waste collected</td>
<td></td>
</tr>
<tr>
<td>Litres of diesel</td>
<td>3.26</td>
<td>8.41</td>
</tr>
<tr>
<td></td>
<td>consumed (per tonne of waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td>collected)</td>
<td></td>
</tr>
<tr>
<td>CO₂ emissions</td>
<td>8.58</td>
<td>22.17</td>
</tr>
<tr>
<td></td>
<td>(kg per tonne of waste collected)</td>
<td></td>
</tr>
</tbody>
</table>

As compelling as the evidence is for the greater efficiency of single modal vehicles, this collection method may not be the most operationally appropriate when factors such as the density and relative compactability of the wastes and the available site space are considered. The results of this report therefore provide useful additional
information on comparative fuel and emissions performance of refuse collection vehicles when considering the design and optimisation of collection systems.
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Acknowledgements

Many thanks Tim Rhodes, Roger McNair from Fuel Harmonics and Wayne Clark from Premier waste for their co-operation and assistance to complete this trial.
1.0 Introduction

1.1 Background

Key to delivering the WRAP objectives of reducing Construction, Demolition and Excavation Waste (CDEW) to landfill (and associated carbon emissions) is the development of efficient logistics systems from the point of collection to delivery for treatment or processing. WRAP’s construction programme is aimed at helping industry achieve the objectives set out in the Government’s Waste Strategy Review and the Construction Commitments: Halving Waste to Landfill.

Whilst the waste sector has developed new technologies and infrastructure over the past 10 years for recycling and the recovery of waste, the logistics of commercial waste collections has remained largely unchanged. In order to promote and facilitate good practice, WRAP has funded a programme of research which includes a series of demonstration trials to support the development of the waste (and construction) industry towards a more efficient logistics model for waste collection.

The outcomes of this demonstration trial (one of a series of three) are designed to help inform waste management professionals of the various options available to manage more efficiently the collection logistics of the non-inert waste fractions. The focus is on the waste management contractors (WMCs) and how they manage the movement of primarily mixed wastes, considering issues of transport method, vehicle selection and approach to logistics planning. This document is a secondary report of the WRAP MRF 114 project with the main report being the ‘Analysis of Collection Logistics for the Transportation of Construction Waste off site for Reprocessing’.

This demonstration trial investigates the potential benefits of the use of the Fitch unit. Fitch units can be retrofitted to most engine types and use a poly metallic amalgam catalyst to improve the quality of the fuel, requiring less fuel to be used. The reduction in fuel required also reduces the NOx and the CO2 emissions¹. The Fitch unit technology has been imported from the USA into the UK under licence by Fuel Harmonics. Results from trial and commercial applications in the USA indicate that the Fitch unit improves the fuel efficiency of combustion engines across a number of marine, rail and road transport applications. The improvement in the fuel efficiency and in turn the CO2 emission from combustion engines is of particular interest when considering WRAP’s target to reduce CO2 emissions. Some alternative fuels and related technologies delivering similar potential efficiency benefits to the Fitch unit are briefly discussed in Section 1.2 of this report below.

The other demonstration trials in this series include an ‘In-cab technology’ demonstration trial and a ‘Computerised Vehicle Routing System’ demonstration trial.

1.2 Alternative fuels and fuel efficiency technologies

The emission of CO2 is a function of the consumption of fuel, which in the case of refuse collection vehicles (RCVs) is predominantly diesel in the UK. Issues affecting the use of diesel going forwards include increasing costs (that are likely to remain high for the foreseeable future) as well as the cleanliness of the fuel when it is burnt. Listed below are a number of alternative fuels and technologies designed to improve fuel efficiency (in addition to the Fitch unit as trialled and reported here):

- Biodiesel – A blend of diesel and biodiesel where the latter component improves the lubricating properties of the fuel reducing engine wear. Current use of biodiesel in the UK is limited on a commercial scale (although manufacturing sites exist in Motherwell and Hull). However this is the subject of ongoing trials and R&D.
- Hybrid vehicles – Running on a combination of petrol / diesel and electric power. Has been trialled on refuse collection vehicles in Sweden and more recently in the UK (e.g. with electric used to power hydraulic lifts cutting down on engine noise.
- Electric vehicles – Have been deployed on a small scale for waste collection in the UK, e.g. by Lewes District Council to collect dry recyclables. As battery technology improves current range limitations will be overcome.
- Liquid petroleum gas (LPG) – Being used in refuse collection vehicles by a number of operators and local authorities, including Woking Borough Council. There exists a moderate sized network LPG fuel outlets albeit much of the fuel is currently imported.

¹ Telephone interview with Tim Rhodes, Director Fuel Harmonics
Hydrogen fuel cells – Subject to emerging R&D in vehicle applications (e.g. through the London Hydrogen Partnership).

Ad Blue - An additive to vehicle fuelling systems that reduces the NOx emissions. There is no direct impact upon the CO2 other than the improved fuel consumption. Exact figures are not available but the efficiencies are in the region of 5% \(^3\). A separate tank is required for the Ad Blue and availability can be an issue. The tank supply and fitting costs are approximately £500.00 per vehicle. Many modern refuse collection vehicles come fitted with an ad blue tank such as on the In-cab trial skip vehicle.

Efficient engine design - There is an increasing trend towards more fuel efficient engines with truck manufacturers developing more efficient Euro engines that can deliver greater miles per gallon than previous engines. This will have a direct impact upon the emissions from these vehicles.

1.3 Modes of collection

There are two distinctly different modes of CDEW collection that WMCs operate. Due to the logistical differences in the modes of collection it was necessary to test both collection modes. The collection modes are:

- single modal collections using skips and Ro-Ro containers and vehicles;
- multi modal collections using Front End Loader (FEL) and Rear End Loader (REL) containers and vehicles.

1.3.1 Single modal (skip and Ro-Ro container) collections

Single modal CDEW collections made by skip or Roll on-Roll off (Ro-Ro) containers can be characterised as follows:

- for this service mode collections are made on the basis of a single container being picked up from each customer (and an empty container left in its place). Waste is then delivered to a reception facility once loaded on the vehicle\(^4\). There is therefore a high proportion of driving time and vehicle mileage per load collected which can limit the number of lifts achievable to an average of 6 – 10 per day;
- work is typically allocated the day prior to collections being carried out, with this task being done ‘by eye’ based on customer proximity and a target number of lifts per day. There are some regular lifts (e.g. every Friday) for larger projects within most daily schedules but these typically represent up to one third of the workload;
- collection routing is typically undertaken by the driver based on local knowledge and the list of jobs assigned for the day;
- for new jobs coming in during the day the driver may have to return to the depot/office to pick up any relevant paperwork before making the collection;
- it is quite rare for specific collection timeslots to be requested (or offered) – this would only be agreed as an exception to the norm (e.g. where the site is unmanned and requires a key holder to be present at a certain time); and
- collections are typically made over five days, with some Saturday morning collections where necessary (acknowledging increased costs due to overtime payments).

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\(^2\) http://www.london.gov.uk/lhp/

\(^3\) Interview with Kath Brown, Transport Manager Midlands (2009), Biffa

\(^4\) Some operators use trailers to support the collection of two skips on the same vehicle, albeit this is uncommon.
The daily format of this type of collection system is shown in Figure 1.1.

**Figure 1.1** Schematic presentation of a single-load CDEW collection system

As the diagram shows the main logistics considerations are associated with how to route each job between point of collection and drop-off and how to sequence the jobs within the day’s work.

### 1.3.2 Multi modal (wheeled bin, FEL and REL) collection rounds

For collections made via multi-modal container systems, meaning multiple containers (typically 1,100 litre wheeled bins, FEL and REL containers) or tipped loads can be collected on a single vehicle ‘round’, the following characteristics apply:

- these collections tend to involve a more static client base than the single modal collections. Where wheeled containers are used to store waste on site collection rounds are set up servicing a range of customer types, so CDEW is likely to be collected (from transient customers) alongside other (C&I) waste material from a relatively fixed client base;
- the common use of compaction vehicles for these collections with sequential pick-ups being made until the vehicle is full means an average of 120 lifts per day might be made on this type of service (covering 70 - 80 customer locations for 1,100 litre containers);
- new customers are typically added to rounds manually by hand - they are rarely formally routed meaning the schedules evolve over time;
- collections tend to be managed on a zonal basis, e.g. Round 1 operates in South Birmingham on a Monday, with drivers having local knowledge of the zones they cover; and
- collections may start as early as 4am, meaning double-shifting of vehicles may be possible.
The daily format of this type of collection system is shown in Figure 1.2 below.

**Figure 1.2** Schematic presentation of a multi pickup CDEW collection system

Within this type of system the question of optimum routing is more complex as there are multiple combinations of collection ordering combinations that might be considered. As the WMC builds customer route density the service becomes more cost effective. Due to the temporary and geographically disperse nature of CDE projects most WMCs operate these collections combined with other Commercial and Industrial (C&I) waste collection work using wheeled containers.

### 1.3.3 Operating restrictions and comparison of single modal and multi modal CDEW collections

Certain material types may not be suited to collection by multi modal vehicles, due to their physical nature meaning they cannot be compacted or may damage the vehicle, or due to their size meaning they need to be stored on site in larger containers. Wood / pallets, soils and rubble, metals and some plastics (e.g. window frames) would generally be regarded as non-compactable or unsuited to a mixed waste multi-modal collection, due to either their form or market value. Similarly, there are materials requiring separate management such as hazardous waste and plasterboard. These would typically be collected via skip, Ro-Ro or curtain-side vehicles.

It is therefore likely that a combination of collection types will be suitable for any given site or project during the demolition, site clearance, preparation and construction/commissioning phases.

### 1.4 Trial objectives

As part of the wider MRF 114 project WRAP wished to undertake a series of demonstration trials to highlight logistics related innovation within the waste industry that would help WRAP achieve its key goals of halving waste to Landfill and reducing carbon emissions in the waste industry. The demonstration trials selected showcase where industry innovation and technology transfer can benefit the whole waste industry. Although the main focus of the project is on the logistics benefits of adopting such technology, the wider operational and financial benefits are also considered.
The purpose of the Fuel Efficiency technology demonstration trial has been to test the impact of the innovative Fitch unit upon the fuel efficiency of Refuse Collection Vehicles (RCVs) in a real world situation rather than under laboratory conditions. The overall aim of the trial (and this report) is to encourage the adoption of innovative technologies within the waste management industry where there are environmental and financial benefits.

2.0 Trial approach

This section of the report details the process used to identify the subject for the trial, through to the running of the trial and ultimately to the findings detailed within this report.

2.1 Trial process

The trial process consisted of six discrete tasks. These tasks were:

- the identification of the trial subject;
- the identification of the trial partners / stakeholders;
- defining the trial, including agreement of the trial aims, parameters and timescales;
- delivery of the trial;
- gathering results and analysis; and
- reporting.

2.2 Trial subject

The trial subject has been developed from the initial desk based research undertaken as part of the MRF 114 project. Through the engagement of WMCs and other stakeholders, valid logistics related trial subjects were identified. The Fuel Efficiency trial using the Fitch unit was selected due to the potential logistics benefits for multi modal and single modal vehicle operations and also the potential scalability factor, where the type of waste being collected and the means by which this is done do not represent limiting factors around uptake. The two main potential benefits are reduced emissions through reduced fuel usage, and linked financial savings. This trial therefore tests the hypothesis that the Fitch unit will enable a reduction in fuel consumption (normally measured in miles per gallon, mpg) on RCVs.

2.3 Trial partners / stakeholders

The trial stakeholders include the sponsor (WRAP), the trial manager (Entec), the technology provider (Fuel Harmonics) and the waste management company (Premier Waste). The figure below shows the interaction flow between the stakeholders. The trial partners were Fuel Harmonics and Premier Waste who actually implemented the trial under the guidance of Entec.
WRAP works with businesses and individuals to help them reap the benefits of reducing waste, develop sustainable products and use resources in an efficient way. WRAP provided financial support for the trial.

Entec is a multidisciplinary engineering and environmental consultancy offering both a breadth and depth of service to provide commercial and technically robust business solutions. Entec has provided consultancy services to WRAP across multiple waste disciplines including best practice guidance and case studies. Entec managed the day to day running of the trial as the project manager.

Premier Waste is a medium sized WMC that operates a transfer station in the north of Birmingham. Premier waste operates 14 vehicles that collect from Birmingham city and the surrounding area. The transfer station can process between 600 and 800 tonnes of waste per day and the company has a turnover of £11 million per annum. Premier Waste are a signatory to the Construction Commitment: Halving Waste to Landfill.

Fuel Harmonics are the sole distributor of the Fitch Fuel Catalyst (Fitch unit) in the UK. The Fitch unit has the potential to improve the quality of the fuel, improving the fuel's performance and thus reduces the fuel requirements. The Fitch unit has applications in marine, road, rail and industrial applications. The Fitch unit has been transferred from the US market where over 1 million units have been sold.

The definition of this trial was based upon the key objectives from WRAP of reducing waste to landfill and also reducing CO₂ emissions. The trial focus is upon the logistics of waste collection and therefore this trial has monitored the efficiency of fuel consumption with and without the Fitch unit.

The units of fuel consumption measurement are miles per gallon (mpg). Within this trial Btrack units were installed on the target vehicles to collect accurate mpg data. The Btrack unit is a fuel measurement tool that can be fitted to most road going vehicles. The Btrack unit measures the flow of fuel and uses GPS tracking technology to measure distance travelled, enabling an accurate measurement of fuel consumption.
The vehicles selected have defined geographic areas of operation and have operated in the same areas and manner throughout the trial. It has been assumed that although individual collections may vary, the overall work and loading of the vehicle is comparable week to week.

The trial has been undertaken using three refuse vehicles, two multi modal and one single modal. The trial collected data using the fuel consumption monitoring equipment called Btrack units. The data was collected daily for each vehicle for the duration of the trial.

The daily data collected to monitor the performance of the trial included:

- the sign in and out time of the driver;
- the trip time;
- the distance travelled;
- the average and max speed;
- the fuel used; and
- the miles per gallon used for each trip.

This data has been collected for all the three vehicles.

2.5 Delivering the trial

The trial started on the 20 June 2009 and finished on the 22 December 2009. To test the external factors that may affect fuel and engine efficiency a control vehicle was used within the trial. This vehicle was a skip (single modal) vehicle and was operated throughout the times that the Fitch unit has been trialled. This control vehicle was used to test the impacts upon fuel efficiency of external factors such as air temperature. All of the drivers were informed of the trial but none were aware of which vehicle the units had been fitted to as these were fitted during scheduled services. To ensure consistency, as far as practical the same driver was allocated to each of the trial vehicles throughout the trial period (with the sole exception of annual leave where agency drivers or other staff are used).

The trial started with all three vehicles having the Btrack units fitted to monitor the normal state fuel efficiency of the vehicles. Half way through the trial the two test vehicles were fitted with the Fitch units to test the fuel consumption for the second part of the trial. The Fitch units were fitted on the 10 and the 12 of October 2009. The control vehicle continued to run with the Btrack unit but without a Fitch unit.

The trial tested a 26 tonne Dennis Eagle RCV vehicle (multi modal) and two 26 tonne Mercedes Atego (single modal) skip vehicles. The single modal vehicles were both registered in 2002 whilst the multi modal vehicle is a 1999 registered vehicle.
2.6 Findings and analysis

The data gathered as listed in section 2.4 forms the basis of the results and the analysis of this trial.
The analysis draws on the findings presented in a report from the Millbrook vehicle testing centre as well as the data gathered directly from the Premier Waste vehicles. The Millbrook report tested the fuel efficiency impacts of the Fitch unit upon a freight vehicle used by John Lewis\(^5\). The assessment also uses the commentary from Fuel Harmonics' own analysis of the trial data.

A web portal was used to gather the data from the Btrack unit by Fuel Harmonics and Entec (albeit with some availability restrictions on occasions).

### 2.6.1 Daily fuel efficiency

The total fuel used and the total miles travelled each week were calculated and assessed to see if applying the Fitch had any effect on the total fuel used per week. Weeks 25 and 52 were excluded from the assessment because they were not full weeks due to problems with the vehicles.

Each day’s work consisted of a number of journeys. These journeys varied from less than a mile to over 20 miles. The miles per gallon (mpg) travelled for each journey was provided for each vehicle by the Btrack unit. To calculate the average mpg per day a weighted average was applied to account for the varied journey distances travelled.

### 2.6.2 CO\(_2\) calculation

The CO\(_2\) emission calculation has been undertaken using the 2009 Guidelines to Defra / DECC’s Green House Gas (GHG) Conversion Factors for Company Reporting. The calculation has been undertaken using the Annex 7 data for freight transport and uses the conversion factor for litres of diesel into total Kg of CO\(_2\).

The total fuel consumed by each vehicle each week over the period of the trial was used to determine the kilograms of CO\(_2\) produced each week by each vehicle.

### 2.6.3 Financial calculation

Fuel savings have been calculated using a standard pump price for Diesel of £1.10 per litre (correct 31st January 2010). Other financial calculations are based upon data provided from Premier Waste and are identified in further sections of this report.

### 2.7 Trial technology

The following section details the technology used in the trial.

#### 2.7.1 The Btrack unit

The Btrack unit measures the flow of fuel to the engine. The modular unit is fitted to the engines’ fuel intake and the fuel flowing through the engine can be measured and monitored. The distance travelled is calculated via a GPS system within the Btrack unit.

The Btrack unit is easy to install and can be fitted by any qualified vehicle fitter or mechanic trained to MOT standard. The Btrack is a robust unit capable of withstanding the daily operations of a waste collection vehicle.

US testing of the Btrack indicates the tolerance of the Btrack is in the region of 0.2%. This is considered to be suitable for the purposes of this trial.

#### 2.7.2 The Fitch unit

The Fitch unit is a modular catalyser using a variety of metals to increase the efficiency of the fuel by increasing the length of the molecular chains that make up the fuel. This improves the quality (or octane value) of the fuel that reduces the volume of fuel required for a given task (all other things remaining constant). The long chains are responsible for the production of Cetanes that improve diesel combustion and also increase the density of the fuel so that more power can be obtained from the same volume of fuel. This has the effect of increasing the lubricity of the diesel that promotes extended engine life. The Fitch unit can be fitted in less than an hour with the size of the unit to be fitted being determined by the engine size.

Tests upon US refuse vehicles have indicated fuel savings up to 10-12% are achievable, with an average around 4-5%. Tests in the US and the results from 1 million sales indicate the lifespan of the Fitch unit to be in the

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region of 10,000 hours or 500,000 miles. It should be noted that the diesel used in the US is of a lower quality to that used generally in the UK. The Fitch unit has not been tested on other refuse vehicles within the UK but has been tested on freight vehicles for John Lewis.

Figure 2.4 shows the Fitch unit and the fitting equipment required.

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**Figure 2.4** Fitch unit and the fitting equipment required

3.0 **Trial findings and analysis**

3.1 **Trial results**

This section of the report details the results obtained from the Fuel Efficiency trial.

3.1.1 **Fuel efficiency results**

The data is displayed in a series of bar graphs that display the data per week. The graph shows the maximum, minimum and average fuel efficiency for that week (as mpg). Week 42 (calendar week) is not displayed as this is the week that the Fitch units were fitted to the other two vehicles (10 and 12 October 2009); no data was recorded for any of the vehicles this week.

Figure 3.1 shows the fuel efficiency results of the control vehicle (BD02 MZL) over the period of the trial.
Figure 3.1 Fuel efficiency (in mpg) for the control vehicle

<table>
<thead>
<tr>
<th>Week</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>12.00</td>
<td>1.00</td>
<td>9.00</td>
</tr>
<tr>
<td>26</td>
<td>11.00</td>
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</tr>
<tr>
<td>36</td>
<td>1.00</td>
<td>12.00</td>
<td>6.50</td>
</tr>
</tbody>
</table>

It can be seen from the graph above that the control vehicle (without Fitch unit fitted) delivers a fairly consistent fuel efficiency of 9-10 mpg over the trial period.

Some very low (minimum) mpg figures reduce the averages outside of 9-10 mpg band. The very low figures presented are linked to short journeys (often a few hundred yards) where the vehicle may not have changed out of first gear. Within the overall analysis a weighted fuel efficiency figure was calculated against the data points to account for the variation in journey lengths driven over the normal working day. However, some low readings have come through but these do not affect the overall averages observed.

Figure 3.2 shows the fuel efficiency results of the single modal trial vehicle (BD02 MZJ) over the period of the trial.
The single modal trial vehicle, prior to the fitting of the Fitch unit in Week 42, delivers an average mpg result in the region of 9.5-10.5. After the Fitch unit was fitted there are proportionally more low results (reduced fuel efficiency) that have the impact of reducing the average fuel efficiency to 6 mpg. The average mpg is displayed as a weighted average based upon the distance travelled. The lower average seen after the Fitch units were fitted may in part be due to the number of short journeys undertaken or that the drivers driving style changed. Premier did not however identify any significant change in the client base throughout the trial. These may, however, be a potential cause of the reduced average trend after the fitting of the Fitch unit.

If the averages skewed by the extreme low mpg data are ignored the data indicates little or no change to the mpg rate with 10 mpg being the norm.

The slight variation between the overall average mpg between the trial and the control vehicle is approximately 0.5 – 1 mpg and is most likely to be attributed to variations in driver style. A 4% reduction in fuel consumption on an overall fuel efficiency of 10 mpg is 0.4 mpg, highlighting the difficulty of identifying such a saving on vehicles with so many variables.

Figure 3.3 shows the fuel efficiency results of the multi modal vehicle (W17 STE) over the period of the trial.
The multi modal vehicle achieved an average weighted fuel efficiency of 3.5 - 4.5 mpg prior to the Fitch unit being fitted. Once the Fitch unit is fitted the range of average mpg figures found is 3 - 4.5 mpg. The lower mpg figures are due partly to some shorter distances being travelled compared to the norm. If the skewed data is ignored the weighted average appears to be around 4 mpg. This is not significantly different to the data gathered prior to the Fitch unit being fitted.

Figure 3.4 illustrates the mpg achieved by the trial vehicles and includes a linear trend line to identify any trends for the mpg achieved during the trial.

The multi modal vehicle has a decreasing average mpg for the duration of the trial. The single modal control vehicle (BD02 MZL) has an improving mpg whilst the test single modal vehicle (BD02 MZJ) has a reducing average mpg during the trial.
3.1.2 Fuel efficiency observations

It can be seen from Figure 3.1 through to and including Figure 3.4 above that the fuel efficiency of the multi modal vehicle is lower than that of the two single modal vehicles. There is a significant difference in the fuel efficiency with the multi modal vehicle achieving an average of 4 mpg whilst the single modal vehicles achieve 9.5 to 10 mpg. The older age of the multi modal vehicle may contribute in part to the lower mpg but the mode of operation with its short trip, start-stop mode of working and the operation of hydraulic lifting equipment is likely to contribute to the low mpg achieved.

For all vehicles when operational issues have occurred such as breakdowns the mpg is either very low or zero. As these are normally rectified within 24 hours they are unlikely to significantly affect the results of the trial.

The results of this trial have not demonstrated that the Fitch unit has any positive effect upon the fuel efficiency of the two waste collection vehicles tested. The Btrack unit used to record data has been confirmed as fully functioning throughout the trial period.

The results of this trial are contradictory with an improvement in the mpg being achieved on the control vehicle. This would indicate that external factors that are not common to each vehicle such as driving style (that the control vehicle cannot assess) have led to the inconclusive results. A trial over a longer period of time may provide more reliable data, however there is no indication that the trial was not operated correctly as reported above.

3.1.3 CO₂ emissions

The emissions of CO₂ from the vehicles will follow a similar trend to that of the mpg, as these are a function of the amount of fuel burnt. The unit CO₂ emissions will be higher for the multi modal vehicle due to a lower mpg.

The trial has identified that the waste collection vehicles tested produce between 600 and 1,000 kg of CO₂ per week. This equates to between 31,200 and 52,000 kg per annum per vehicle. The emissions for the different vehicle types are similar due to the combination of the distance travelled and the fuel efficiency; although the
single modal vehicles are twice as efficient as the multi modal vehicle, they also travel twice as far on average. From the trial the single modal vehicles were seen to travel between 560 - 685 miles per week whilst the multi modal vehicle 250 – 375 miles per week.

Through the data gathered on this trial, supported by information researched on the wider MRF114 study, high level statistics describing typical operating parameters for single multi modal collections have been developed. These are shown in Table 3.1.

Table 3.1 Summary single modal and multi modal operating statistics

<table>
<thead>
<tr>
<th></th>
<th>Single modal vehicle (14 yd skips)</th>
<th>Multi modal vehicle RCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average weight collected (tonnes per day)</td>
<td>18*</td>
<td>7.28</td>
</tr>
<tr>
<td>Average mpg</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Average distance travelled (miles per week)</td>
<td>650</td>
<td>272</td>
</tr>
<tr>
<td>Average litres of fuel consumed (per week)</td>
<td>293</td>
<td>306</td>
</tr>
<tr>
<td>Average CO2 emissions (kg) per week</td>
<td>772</td>
<td>807</td>
</tr>
</tbody>
</table>

* based on an average 3 tonnes each and 6 jobs

Table 3.1 indicates that there is a similar amount of CO2 produced by the single and the multi modal vehicles within an average week of work based upon the data gathered during the project.

From the statistics above, Table 3.2 shows the distance travelled, litres of diesel consumed and CO2 emissions reported against the functional unit of ‘tonne of waste’ collected. This analysis was undertaken as additional work to see if any conclusions can be drawn on the overall environmental performance of one mode of collection versus another.

Table 3.2 Distance travelled, fuel consumed and CO2 emissions per tonne of waste collected

<table>
<thead>
<tr>
<th></th>
<th>Single modal vehicle 14 yd skip</th>
<th>Multi modal vehicle RCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance travelled (miles per tonne of waste collected)</td>
<td>7.22</td>
<td>7.47</td>
</tr>
<tr>
<td>Litres of diesel consumed (per tonne of waste collected)</td>
<td>3.26</td>
<td>8.41</td>
</tr>
<tr>
<td>CO2 emissions (kg per tonne of waste collected)</td>
<td>8.58</td>
<td>22.17</td>
</tr>
</tbody>
</table>

Although on the face of it the two different collection methods involve significantly different daily mileages being driven, when calculated back against the weight of waste collected the average distances are very similar (between 7 – 8 miles per tonne). Within more rural areas this profile would be different, and a disperse customer base perhaps lends itself more to single modal type collections as it is more difficult to build up sufficient route density to justify the use of more expensive compaction vehicles. This situation would perhaps change should there be a trend towards collecting materials based on type / composition rather than origin. Although some commercial and domestic waste collections occur presently this tends to be where the bin type and collection vehicle are compatible.

The fuel required to collect a single tonne of waste using the single modal vehicle is less than half that of the multi modal vehicle. CO2 emissions are directly linked to fuel consumption and as such the multi modal vehicle is far less fuel efficient and produces over twice the CO2 emissions when compared to the single modal vehicle.

Single modal vehicles therefore appear more efficient when moving large tonnages, in terms of fuel consumption and CO2 emissions, in comparison with the single modal example above. This does not mean that multi modal collections are inefficient. Many sites will not have space or suitable logistics on site to use large single modal waste containers. In these cases multi modal collections represent best practice.
3.2 Fuel Harmonics commentary

Fuel Harmonics have undertaken their own analysis of the trial data as a separate validation exercise, focussing on the longer journeys (i.e. over 1.5 miles) to screen out the skewing effect of short runs on the average vehicle fuel efficiency. Consistent with the findings presented in section 3.1.1 this data has not shown any trend to support the hypothesis that the Fitch unit provides a positive effect upon fuel efficiency in waste collection vehicles.

3.3 Practical considerations for implementation

The fitting of the Btrack and the Fitch units to the vehicles is straightforward and requires basic mechanical knowledge that will be possessed by an MOT trained mechanical engineer. The application of these technologies to other companies or indeed the industry is achievable and the skills to fit the technology are widespread and easy to access.

The cost of the Fitch unit for this application is in the region of £400-£500 per unit with the additional costs of the fitter or mechanic for one hour to fit the Fitch unit.

3.4 Trial partner interactions

It has been essential during the commencement, carrying out and completion of the trial to consider and manage the interactions of the trial partners. It is critical to develop relationships at a senior level within the organisations to ensure that the support required is willingly given. This commitment needs to be delivered by operational staff required to give their time to the trial whilst also undertaking their daily tasks.

4.0 Summary and discussion

4.1 Results

It has not been possible from the trial to substantiate the hypothesis that the Fitch unit can improve the fuel efficiency of the waste collection vehicles tested.

One possible explanation for the anomalous results is that the drivers have been driving the vehicles more quickly due to the improved fuel characteristics which have offset any advantage that the Fitch unit can deliver, although this was not picked up through interviews with operations staff at the end of the trial. It is possible that the use of heaters in the vehicles during the cold spell at the end of 2009 could have placed additional loading upon the engine and this may have had a minor impact upon the fuel efficiency of the vehicles, however this should also have been picked up through the control vehicle results - which was not the case. It is possible that other factors such as tyre pressures could have an impact but the vehicles are serviced on a regular scheduled basis so this is unlikely. Inconsistencies and the degradation of bunkered fuel are not considered to have had an impact due to the vehicles all re-fuelling from a common bunker at the Premier Waste depot.

The failure of the Btrack unit to function properly can be discounted due to the low potential for three units to fail. The Btrack units used in this trial were tested prior to use on the trial and the technology is proven.

4.2 The waste industry perspective

The waste industry may be sceptical of emerging technologies such as the Fitch unit. Further work is therefore likely to be required to demonstrate any quantifiable benefits this technology may deliver for the sector.

Tests on refuse vehicles in the USA have indicated around a 5% reduction in emissions and associated fuel consumption. With the Fitch unit costing £400 - £500 (plus the minimal fitting costs) the payback period based on this level of reduction in fuel consumption would be between 2 - 4 months. A typical medium sized WMC operating 20 vehicles on a regional basis is likely to have a monthly fuel spend of £30,000 per month (£360,000 per annum). If the 5% saving were to be achievable this would equate to £18,000 per annum. The investment required to purchase and fit the units would breakeven within the first year.
Fuel Harmonics have been working with a retail client to test the Fitch unit on a freight vehicle. The test has been undertaken at the Millbrook proving ground in Bedford. This trial indicates that a 3% saving in fuel (and associated CO₂ emissions) can be achieved.

### 4.3 Wider findings

The fuel efficiency of the different modes of collection from the trial is significant. There may be some impact with regards to the age of the vehicles but this is unlikely to account for the range in mpg recorded. The single modal vehicles achieve over double the fuel efficiency of the multi modal vehicle. Notably the less efficient multi modal vehicles travel fewer miles per days and thus the CO₂ emissions from a days work for each of the modes is similar. The CO₂ emissions from the vehicles range between 600 - 1,000 kg of CO₂ per day. The sample of vehicles in the trial is too small to extrapolate to the Premier Waste fleet (or the waste industry as whole), however the data does provide a useful set of benchmarks against which further work on waste collection and transport impacts can be developed.

The wider MRF114 study has shown that the daily tonnages collected by the single modal vehicles may be 2 - 3 times higher than that of the multi modal vehicles. This, combined with the greater fuel efficiency of these vehicles, shows that the single modal vehicle collection system is efficient in terms of the tonnages moved. It should be noted that the single modal collection system is not suited to all sites, especially where space to site the large containers is at a premium. The waste material bulk density also needs to be considered as does the compaction ratio of the material. For example metals are not compactable and hence skips are a primary method of collection. Plastic wrapping for pallets is highly compactable and multi modal compaction options are commonplace here. Whilst considering these operational influences on collection method it is also useful to understand the comparative fuel and emissions performance as presented in this report, thus ensuring that the optimum mode is selected for any job.

### 4.4 A fuel efficient future

Waste collection vehicle technology is advancing. The advent of more fuel efficient (Euro engines) and fuel additives such as Ad Blue have improved fuel efficiency and reduced emission levels; these are now mainstream technologies used across the waste industry. Many other technologies are not mainstream within refuse collection but the technology for battery powered vehicles and hybrid technology is improving. Further trials or tests are needed to prove (or disprove) the fuel efficiency claims that the Fitch unit can achieve a 3-5% saving in fuel consumption.